Kent SeaTech Corporation

New Technologies for Treatment and Reuse of Wastewater from Aquaculture Facilities

In the mid-1990s, the $1 billion U.S. aquaculture industry was supplying 25 percent of the fish products sold domestically. Because growth in the industry is limited by the finite supply of fresh water, reuse of water is a prerequisite for the industry's long-term survival and expansion. One of the obstacles that prevented the industry from maximizing its production and effectively competing on the worldwide market was the inefficiency of the methods used to treat and recycle wastewater for agricultural and other uses. Furthermore, the industry needed an economical wastewater recirculation technology that was compliant with Environmental Protection Agency regulations. Kent SeaTech Corporation, a small, 23-year-old company, applied for and received Advanced Technology Program (ATP) funding in 1995 to find more innovative and economical ways to solve this high-risk, capital-intensive challenge.

Kent SeaTech wanted to develop a new three-step process for treating fish tank wastewater. The first step would use a secondary fish species that consumes the waste from the company's primary product, hybrid striped bass. The second step would provide a media for breaking down ammonia waste, and the third step would provide an innovative wetland pond environment to complete the breakdown of the nitrogen-based waste. The company patented the process four years after project conclusion as "SMART-Wetlands." (SMART is an acronym for "suspended media ammonia removal technology.")

Today, Kent SeaTech uses its successful SMART-Wetlands process to produce 3.5 million pounds of hybrid striped bass that they ship globally. In addition, they sell their surplus treated water to nearby farms. Furthermore, at least two nearby businesses have imitated Kent SeaTech's wetlands technology to treat agricultural runoff and municipal sewage wastewater.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
* * *

Research and data for Status Report 95-01-0034 were collected during August – September 2004.

Large-Scale Fish Farm Growth Limited by Scarce Fresh Water Supply

In the late 1990s, fish farming, or aquaculture, was used to raise almost 25 percent of the fish products sold in the United States. An aquaculture facility breeds, hatches, and grows fish in a controlled environment aimed at optimizing a nutritious and flavorful product. Such a facility requires large amounts of fresh water in which the fish grow, but these amounts of water are not always available because of competing municipal demands and scarcity of water in some geographical locations. Therefore, the aquaculture industry needed to find ways to clean and recycle their water without sacrificing product quality or violating Environmental Protection Agency (EPA) regulations. At the time of the project proposal, the state-of-the-art for water filtration was to use filters, an expensive and uneconomical solution. (The goal of filtration in aquaculture is not to make water fit for human drinking, only clean enough to support fish growth.)

In an ideal environment, an "open" system for cleaning the tank water supply is best. In this method, tank water that has been contaminated with fish fecal and ammonia waste, or effluent, is replaced often. But this method was too expensive and generated large amounts of wastewater, which is subject to EPA regulations such as the Clean Water Act and the National Pollutant Discharge Elimination System. Closed systems, which depend on filters to clean the water, are also expensive due to filter costs. Neither the open nor closed system was an economically viable option for the Kent SeaTech Corporation, a 23-year-old privately held fish farming and research company. Kent SeaTech was looking to develop a "semi-open" water circulation system in which some water would be replaced at regular intervals, some would be recirculated to fish tanks, and some would be recycled to nearby agricultural farms.

The aquaculture industry needed to find ways to clean and recycle their water without sacrificing product quality or violating Environmental Protection Agency (EPA) regulations.

Kent SeaTech wanted to explore new technologies for reducing the extremely high cost of cleaning and recirculating fish tank water. They sought to refine a three-step process for cleaning and filtering wastewater. In order to achieve their goal economically, it was necessary to replace some of the water. The goal, however, was to recycle as much water as possible into the agricultural business. If a successful, cost-efficient method could be developed, two benefits could be realized: the water could be recirculated back into the fish tanks, and extra wastewater that could not be used again could be sold and transported by canal to nearby agricultural farms as irrigation water. This water, containing low concentrations of ammonia and nitrate, acts as a mild fertilizer. If cost effective, Kent SeaTech believed this technology might have applications in other industries, such as municipal sewage treatment.

Kent SeaTech Seeks Funding for Water Reuse Research

Fish farming is a highly capital- and water-resource-intensive operation. Kent SeaTech had exhausted its private funding capital from several sources. The company needed to find alternate sources of funding in order to research and develop a more cost-effective method of recirculating most of the water used in its fish farming tanks.

The Kent SeaTech tank facility was located in the Coachella Valley area (near Palm Springs, California), which had a limited water supply. Therefore, the "semi-open" method of tank water recirculation made the most sense for the company's ATP-funded research focus. So in 1995, the company applied for and received ATP funding for a three-year project to explore new ways to efficiently treat and recycle the wastewater from its hybrid striped bass product. Kent SeaTech and other fish farms in the United States also needed help to effectively compete in global markets such as southeast Asia and other locations that have the economic advantage of no environmental regulation, cheaper labor, and an abundance of naturally warm water. (Although the lack of regulation enables cheap aquaculture operation, some foreign countries have ruined their aquaculture facilities in a short time by polluting their intake water with careless waste disposal. They then incurred heavy expenses to fix the problem.)

Researchers Explore a New Three-Step Process for Tank Water Recirculation

Kent SeaTech successfully developed a prototype of their proposed technology for cleaning and recirculating wastewater, as described below. This process remains in use today at their facility in Coachella Valley.

The first step in the process was the solid-waste-removal "raceway," which was a long concrete tank stocked with freshwater tilapia, a warm-water fish originally from Africa. Fish effluents, consisting of solid and liquid organic wastes from the tanks (see Figure 1), were channeled into the raceway. The tilapia eat organic matter indiscriminately and ingest about 30 percent of the suspended solid waste before the waste decomposes into ammonia and other toxic compounds. In Kent SeaTech's prototype, the tilapia fed only on the effluent from the farm tanks, which included unconsumed striped bass feed.

Figure 1. One of Kent SeaTech's 97 circular concrete fish tanks where hybrid striped bass are raised. Approximately all of the tank water is replaced every 2.5 hours, either by recirculating or by adding water from a geothermal spring. Each tank holds 17,000 gallons. The upright cylindrical silos adjacent to the tanks dispense feed. The short blue cylinders on the left inject oxygen into the tanks in sufficient amounts to sustain and grow the high-density population of fish in each tank.

The second step is the SMART (suspended media ammonia removal technology) system. After leaving the raceway, the wastewater enters a large oval tank where the water is circulated by a hydraulic paddlewheel. In the tank are polyurethane foam cubes that provided a large aerated surface area upon which bacteria could grow. These bacteria break down ammonia, the most common fish waste, into less harmful nitrate. The SMART system can handle 40 percent of the ammonia that remains in the wastewater after it leaves the raceway.

The third step in Kent SeaTech's process is the wetland treatment pond. After the water is treated by the SMART system, it is channeled into a series of wetland pond tanks that are planted with mature bulrush plants. These plants maximize the removal of the nitrogen compounds that result from the breakdown of ammonia and also remove 40 percent of the remaining ammonia that is not yet decomposed. About 64 percent of the remaining waste solids are removed during this final step. The remaining water is then tested; if nitrogen levels are acceptable, some water is returned to the growing tanks, and the rest is channeled to a nearby farm to be used for crop irrigation, where the remaining nitrates contribute to crop growth. The wetland pond also reduces the wastewater temperature in summer to below 27ºC, a temperature that is more optimal for growing striped bass. This step completes the recirculation of the water. An unexpected positive outcome in this step is that the ponds also create a bird habitat.

During the project, Kent SeaTech received assistance in designing the SMART system, including the paddlewheel, from Clemson University in South Carolina. The company received assistance in designing the ponds from the University of California in San Diego.

ATP Enables Farm Expansion

Before the project started, Kent SeaTech, with headquarters located in Palm Springs, California, found inexpensive land in the Coachella Valley on which to expand their facilities. Ninety-six circular tanks had been completed prior to the project start in 1993. With ATP funding, by fall 1996, the raceway, the SMART system prototype (including the test tanks), 28 wetland ponds, water pipes, and the test instrumentation were in place. By the end of 1996, Kent SeaTech had built a water quality analysis lab, had transitioned from fish solid waste sludge treatment for ammonia to the foam cubes for nitrification, had stocked the raceway with 50,000 pounds of tilapia (or about 200,000 quarter-pound fish), and had planted the bulrushes in the wetland ponds. The company also added the raceway along with other buildings that would house the necessary machines and instruments to supply and monitor the condition of the tank water.

Project Experiences Early Successes

The raceway provided an early and unexpected benefit to Kent SeaTech and became the company's most significant source of cost reduction. The tilapia grew quickly by ingesting the striped bass' uneaten food and solid waste effluent. They were suitable for sale in California. The profit from the sales more than offset the cost of operating and maintaining the raceway.

The second water-filtration step, the SMART system, was initially less successful. The soft polyurethane cubes that provided surface area upon which the bacteria could grow eroded too quickly. Subsequently, the eroded cubes posed a particulate waste problem when they became small enough to pass through the filters into the bulrush wetland ponds. By the end of the

ATP-funded project, Kent SeaTech was seeking a more durable SMART media.

The company spent about $500,000 of its own funds after the conclusion of the project in part to consult with two California plastics companies, Inline Plastics and Talco Plastics, on how to design and build a harder, more durable SMART media. Subsequently, Kent SeaTech developed a product made from recycled plastic beverage bottles that have an estimated useful life of 15+ years. Talco contributed to the success of the improved media by adding talc to make the plastic harder, and Inline Plastics assisted in designing the media by adding carbon to the plastic during manufacturing. The carbon made the polyethylene black, rendering it nearly immune from the degrading effects of sunlight. (Polyethylenes are stable in the environment and on disposal have no adverse impact on municipal water-handling or incineration processes and landfills.)

The new SMART media design was a half-inch shape with a wavy surface to which the bacteria could cling. Kent SeaTech patented this design in November 2002. The success of this SMART media developed jointly by Kent SeaTech and Talco was a major breakthrough in the cost-effective operation of Kent SeaTech and the industry as a whole. Prior to the joint effort, the industry had been using plastic media of various types and sizes, but none of them were cost effective. Kent SeaTech also used a portion of its $500,000 investment to expand its wetlands and to install drum filters between the raceway and the wetland tanks. The drum filter enhancement helped remove the smaller particulate matter that the tilapia did not ingest.

Project Achieves Water-Recycling Goals

The ATP-funded project achieved another of its goals: providing suitable water for an agricultural farm located a quarter mile from the Kent SeaTech facility and also for a local duck hunting club. The treated wastewater for the farm still contained nitrogen, which was beneficial in growing corn and lettuce. Kent SeaTech was able to sell its wastewater to the farm for $16 an acre-foot, which was $2 less than the farm had been paying for water from a pump source of the county water agency. (An acre-foot is the amount of water that covers one acre of land at a depth of one foot.) The Kent SeaTech-treated water was also less salty than pump water, saving the agricultural farms the cost of desalinization.

Kent SeaTech wanted to explore new technologies for reducing the extremely high cost of cleaning and recirculating fish tank water.

A spillover benefit was increased crop yields for farmers who used the treated wastewater. After a local vegetable grower used recycled water for irrigation, crop yields increased by about 10 percent, and fertilizer costs were reduced by 15 percent due to the nitrogen content left in the wastewater. This aspect of the program encouraged Kent SeaTech to plan the expansion of their water sale program to a 300-acre vegetable farm located 1.5 miles from their facility. By 1998, Kent SeaTech had installed a 24-inch pipe to the farm, through which the company sells 2,500 acre-feet of recycled water per year. In addition, the pipe supplies treated water to three nearby duck hunting clubs.

Although the revenue from selling recycled water to agricultural farms and hunting clubs represents less than one percent of Kent SeaTech’s annual revenues, the company, as a resident business in a farming community, is committed to the water recycling program. As a result of developing the SMART-Wetlands process, Kent SeaTech has reduced its water cost from $70 per acre-foot to $26.50 per acre-foot.

Kent SeaTech Uses Carp in Winter Months

As of 2004, Kent SeaTech is using a combination of tilapia and carp in the raceway to reduce the loss of warm water in the winter months. (The tank water is supplied from a geothermal spring.) This efficiency is achieved by putting the carp and the tilapia in separate compartments in the raceway. Some tank water is allowed to bypass the wetland ponds, where normally it would cool too much to encourage fast growth for the bass, which need a certain water temperature to optimize growth.

Bypassing the ponds also enabled the water to stay warmer and be channeled back into the bass-growing tanks, which has helped the bass to grow faster.

Because carp can tolerate colder water than can tilapia, carp are used in the raceway in the winter months. Kent SeaTech loses less heat in the tank water in the winter months by bypassing the wetland pond filtration stage, where the water cools by another 2°C to 3°C.

ATP Funding Was Critical for Technology Development

While it is difficult to determine exactly how many years of development time the ATP funding saved, Kent SeaTech could not have achieved its successes without ATP help. In 1995, the company was unable to identify other sources of funding. For example, Kentco Capital of Northfield, Illinois, a venture capital firm owned by Richard Kent, the CEO of Kent SeaTech, was unwilling to supply funding to the project until the company had documented some success in achieving its goals. After the company demonstrated initial success with ATP funding early in the project's first year, Kentco was willing to grant a 24-percent funding match to the ATP funding for the remaining 3 years of the project. Otherwise, Kentco Capital would not have funded the effort.

The success of this SMART media developed jointly by Kent SeaTech and Talco was a major breakthrough in the cost-effective operation of Kent SeaTech and the industry as a whole.

Success of the ATP-funded technology has enabled Kent SeaTech to dramatically increase its fish production. Today, the company produces 150,000 pounds of tilapia per year and 75,000 pounds of carp from the raceway. The company also produces 3.5 million pounds of hybrid striped bass annually from 97 circular concrete tanks on 160 acres, which is about one-third of the total U.S. production of striped bass.

ATP enabled Kent SeaTech to develop a practical solution with real economic benefits. The biologists who founded Kent SeaTech estimate that of the 4,000 aquaculture facilities in operation today in the United States, approximately 245 discharge a million gallons of wastewater per day, more than 30 days a year. Because this discharge is subject to EPA regulations, the facilities' opportunity for process improvement is enormous if they convert to the Kent SeaTech wastewater treatment process.

Technology Contributes Other Spillover Benefits

Information about Kent SeaTech's processes has been published in local newspapers and has inspired the following additional technology spillovers:

- The Valley Sanitation District of Indio, California built a 16-acre wetland to process sewage and bought bulrush plants from Kent SeaTech.

- The Torres Martinez Indian Reservation near Yuma, Arizona used the wetlands technology to treat water with excessive amounts of agricultural runoff.

- Kent SeaTech entered into a joint venture with Aquaculture Systems Technologies of New Orleans, Louisiana to improve the design of a new bead-filter technology consisting of small plastic beads for small-scale or laboratory applications. Kent SeaTech adjusted the bead-filter design for their outdoor tanks that subjected the bead filters to more stress, such as large mixing propellers. (Durable plastic oblong beads are another type of media upon which bacteria can grow to help dispose of the byproducts of particulate decay in tank water.)

- Recognizing the dependence of future U.S. fish farming on water recirculation technology, Kent SeaTech secured additional Federal research funding from the U.S. Department of Agriculture and the National Science Foundation to promote the Joint Aquaculture/Agriculture Water Sharing (JAWS) program. Also, Kent SeaTech is working with Clemson University to explore solutions to the limited availability of water supplies for U.S. aquaculture development. The focus of the research is a combined water-sharing and nutrient-recovery approach between fish farms and agricultural farms.

- Company researchers have also shared their project knowledge through 18 published articles and 8 presentations.

Conclusion

Kent SeaTech, a fish-farming company, wanted to explore more efficient and cost-effective methods to clean and recycle wastewater in its fish tanks to maximize production of its hybrid striped bass that the company ships globally. The company's proposed new technology involved a series of improvements to Kent SeaTech's three-step system, known as "SMART-Wetlands." (A patent for the basic three-step process was granted to Kent SeaTech on September 10, 2002.) This system not only cleaned and recirculated some of the tank wastewater, it also provided nitrogenated water for agricultural crop irrigation. The company experienced quick success with the first step of the process: a tank stocked with tilapia, a fish that thrived on the striped bass' uneaten food and particulate waste. The tilapia quickly grew to a size suitable for sale in local and global markets. For the second step of the wastewater-cleaning process, Kent SeaTech developed a durable plastic media upon which nitrifying bacteria, which consume nitrogenous wastes, could grow, thus cleaning the tank water. Kent SeaTech perfected the design of this media after the conclusion of the project, which resulted in a second patent for the company. This media was a major contribution in water filtration and recirculation in the industry. The third step, the bulrush wetlands, disposed of the remaining solid waste by breaking it down further.

In the post-project period, Kent SeaTech increased its hybrid striped bass production by 50 percent, due to the addition of more tanks that increased the capacity to feed and hold more inventory and treat more water. The company produces 150,000 pounds of tilapia and approximately 3.5 million pounds of hybrid striped bass per year, which is about one-third of the U.S. industry's total of 11.5 million pounds of striped bass.

Recognizing the dependence of future U.S. fish farming on water-recirculation technology, Kent SeaTech secured additional Federal research funding from the U.S. Department of Agriculture and the National Science Foundation. With the additional funding, the company will promote the Joint Aquaculture/Agriculture Water Sharing, a program with Clemson University, whose purpose is to explore, maximize, and encourage ways to create fish farming and land crop agriculture cooperative businesses.

PROJECT HIGHLIGHTS
Kent SeaTech Corporation

Project Title: New Technologies for Treatment and Reuse of Wastewater from Aquaculture Facilities (Development of New Technologies for Treating and Recirculating Wastewater from Aquaculture Facilities)

Project: To develop new wastewater treatment technologies that are a cost-effective means of removing fish farm effluents to allow for water reuse in aquaculture and for irrigation of agriculture crops.

Duration: 8/15/1995–8/14/1998
ATP Number: 95-01-0034

Funding (in thousands):

ATP Final Cost	$1,996	67%
Participant Final Cost	993	33%
Total	$2,989	

Accomplishments: With ATP funding, Kent SeaTech accomplished the following:

- Developed a viable technology to recycle tank water containing nitrogenated fish waste that benefited agricultural crop production.
- Was the first in the industry to develop and patent a durable plastic media for nitrifying tank waste (see patent title below, "Biofilm carrier element.")

Kent SeaTech generated the following patents for its wastewater technology:

- "Partitioned aquaculture system"
(No. 6,192,833: filed March 16, 1999; granted February 27, 2001)
- "Aquaculture wastewater treatment system and method of making same"
(No. 6,447,681: filed August 7, 2000; granted September 10, 2002)
- "Biofilm carrier element"
(No. D465,257: filed September 24, 2001; granted November 5, 2002)

Commercialization Status: The company developed a successful and economical process for treating fish tank wastewater; the process has enabled them to increase their fish production to 3.5 million pounds of hybrid striped bass, sold worldwide. They also produce two secondary fish, tilapia and carp, which they sell to live fish markets in California.

In addition, the company sells treated fish tank water for recycling to local agricultural farms. The treated water contains low concentrations of ammonia and nitrate, which act as a mild fertilizer for agricultural irrigation. Several fish farm businesses are using methods that consist of one or more of the three steps of Kent SeaTech's patented wastewater treatment system.

Outlook: The outlook for this technology is excellent for fish farms situated near a geothermal water supply and arable land suitable for using the treated wastewater.

Composite Performance Score: * * *

Number of Employees: 70 at project start, 75 as of August 1998

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Subcontractors:

- Clemson University
Clemson, SC
- University of California
San Diego, CA

Publications: Kent SeaTech received public attention through the following publications:

- Dower, Rick. "Aquatic systems reaps wet rewards in the desert," *San Diego Business Journal*, 9:6, August 29, 1988.
- Van Olst, Jon C., and J. M. Carlberg. "Commercial Culture of Hybrid Striped Bass: Status and Potential," *Aquaculture Magazine*, 16:1, January/February 1990.
- Tsai, Donna H. "There's Something Fishy Going On in The Desert," *The Press Enterprise*, August 20, 1995.

PROJECT HIGHLIGHTS
Kent SeaTech Corporation

- Hale, Christine W. "Who Grew That Fish on Your Plate?" *Sunset Magazine*, August 1995.
- "From Fish to Vegetables," *American Vegetable Grower*, December 1995.
- Martin, Rick. "Kent SeaFarms: On-Site Tour," *Fish Farming News*, Vol. 3, November/December 1995.
- "Fish Farming Tipping the Scales of Success," San Diego Business Journal, 17:26, June 24, 1996.
- Carlberg, James. "Semi-Closed Cycle Striped Bass Culture, Coastal Aquaculture in California," *Marine Technology Society*, November 14, 1997.
- "Keeping Up with Seafood Demand," *Seafood Business*, January/February 1997.
- "Fish Farms Get Hooked on High Tech," *San Diego Business Journal*, 19:4, January 26, 1998.
- Carlberg, James. "The Hybrid Striped Bass Culture Industry: History, Current Status, and Research Needs," *World Aquaculture Society*, February 1998.
- Massingill, Michael. "Implications of Water Reuse on Productivity and Economics of Striped Bass Farming," Striped Bass Growers, February 1998.
- Carlberg, James. "Striped Bass Culture Industry Case Study," *Marine Aquaculture: Emerging Technologies and Global Opportunities*, June 1998.
- Carlberg, James. "The Growth of the Striped Bass Aquaculture Industry," *Striper 2000: Research Advances on Striped Bass and Its Hybrid*, June 1998.
- "Marine Aquaculture: Emerging Technologies and Global Opportunities," University of Connecticut, June 1998.
- "Striper 2000: Research Advances on Striped Bass and Its Hybrids," University of Maryland, June 1998.
- Carlberg, James. "The Production and Sales of Hybrid Striped Bass in 1998," *World Aquaculture Society*, January 1999.
- Massingill, Michael. "Aquaculture Permiting: California and Arizona, a Study in Contrast," *Western Regional Aquaculture*, February 29, 2000.

Presentations: Kent SeaTech also disseminated knowledge through the following presentations:

- Second International Conference on Recirculating Aquaculture, "Constructed Wetlands for Water Treatment in Aquaculture." Roanoke, VA, July 1998.
- Massingill, Michael J., Kent SeaTech Corporation. "Aquaculture and Agriculture: A "Win-Win" Partnership for Expanding Production Through Multiple-Use of Existing Water Supplies." Presented in "Future Workshop," Advanced Technology Program National Meeting, San Jose, CA, November 17, 1999.
- Massingill, Michael J., Kent SeaTech Corporation. "Tilapia for Particulate Removal." Presented at the Aquaculture Engineering Society Forum, Raleigh, NC, November 1999.
- Massingill, Michael J., Kent SeaTech Corporation. "Large Volume Nitrification Reactors." Presented at the Aquaculture Engineering Society Forum, Raleigh, NC, November 1999.
- Massingill, Michael J., Kent SeaTech Corporation. "Constructed Wetlands For Aquaculture Solids, Nitrogen, Alkalinity, and Temperature Control." Presented at the Aquaculture Engineering Society Forum, Shepardstown, WV, November 12, 2001.
- Massingill, Michael J., Kent SeaTech Corporation. "Hybrid Striped Bass: An Emerging New Species?" Presented at the 4th International Conference on Recirculating Aquaculture, Roanoke, VA, July 18-21, 2002.
- Massingill, Michael J., Kent SeaTech Corporation. "Western Aquaculture, Promises & Pitfalls." Presented at the Western Regional Aquaculture Conference, Reno, Nevada, March 13, 2003.
- Massingill, Michael J., Kent SeaTech Corporation. "The Impact of Fish Density on Net Productivity." Presented at the California Aquaculture Association Conference, San Diego, CA, January 30, 2004.

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